National Facilities

A report to the National Committee for Astronomy for the Australian Astronomy Decadal Plan 2006-2015
By Working Group 3.2

September 2005

Executive Summary

Australia's national facilities for observational astronomy are the Anglo-Australian Observatory (AAO) and the Australia Telescope National Facility (ATNF). In the period covered by this Decadal Plan the United Kingdom will substantially reduce its contribution to the operations budget of the AAO. In consequence, a major issue for this WG to consider is the future funding of the AAO.

In addition to the AAO and ATNF, several Australian universities operate observing facilities that have a significant role at a national level: either by offering observing time to outside users or by providing infrastructure as in the case of the ANU's Siding Spring Observatory (SSO). Rather than duplicate the detailed discussions of these facilities, the three Facilities WG chairs agreed to assign facilities like SSO into one or the other WGs: this was for practical reasons and does not imply any judgement about the status of the respective university facilities.

Our discussions at this stage of the Decadal Plan process were independent of the scientific priorities from the science WGs, so are based mainly on strategic issues informed by the submissions we received and our own experience as users (and senior staff) of national facilities.

The lack of a detailed science case at this stage of the process makes it hard to assign relative ranks to all the facilities discussed. However we have identified the top and bottom items:

- In all our discussions there was unqualified support for the AAO and ATNF as our two national facilities. This is further supported by the publication impact analysis submitted by WG3.1. We therefore give them top priority for continued full support, notably extra support for the AAO in the context of diminished UK funding. To quote the report of the optical sub-group at the second public meeting:

  > *"It is absolutely vital that the AAO as an institution be kept running, in order to retain the people, intellectual property, and instrument R&D/construction capability."*

- We are very aware that we must be willing to consider closing some facilities if we are to obtain funding for new ones. To this end we have identified facilities that may not be needed in the second half of the decade and list them at a lower priority. The ICT resources, although essential, are small and most likely to be funded elsewhere, so we have also placed them at a low priority.

The WG noted very strong support for the continued operation of the ANU Siding Spring Observatory to provide the infrastructure for Skymapper and smaller telescopes on a national level. This needs additional funding (perhaps by a new mechanism), as do many of the Australian university facilities.

Facilities like SSO and new proposals such as PILOT, when combined with international facilities, will cost more than we can realistically hope to raise, so further decisions about these are necessary which will be guided by the science priorities.

The following list describes the specific facilities we discussed and supported. More detailed descriptions of the facilities are given in the following pages. This includes a description of the national support for theoretical astrophysics. Whilst this was not listed as a specific facility for support, we encourage the development of plans that allow for the support of theoretical astrophysics within all the national facilities.

National Facilities

- The Anglo-Australian Observatory, funded at the level described below, and including support for our 8m and ELT development. Cost: nominally $5.7M per year although some increase will be required to provide support for the 8m and ELT projects.
- The Australia Telescope National Facility and the currently planned xNTD. The total support for all of ATNF is $18M per year. (SKA pathfinder development work we consider an international project.)

University Facilities

- The Siding Spring Observatory site (run by ANU) to provide vital infrastructure to our optical telescopes. Cost: $4M (including 2.3m) or $3M (without 2.3m) per year, not including recoveries.
- The ANU Skymapper Telescope. Cost included in SSO above.

Proposed New National Facilities

- The extended version of xNTD beyond what is currently funded.
- PILOT (about $12M to build, then $2M/year operations. With international partners, Australia may only need to pay half of this.)

National Facilities for the Next 5 Years

- The ANU 2.3m Telescope. Cost included in SSO above.
- The Australia Telescope National Facility's Mopra telescope.

National Facilities funded outside Astronomy

- Advanced ICT resources, including the Australian Virtual Observatory; access to state-of-the-art super-computers and storage from APAC; and access to national broadband (10 – 100Gbps) networks, notably the fast link to SSO.

Facilities

1. Anglo-Australian Observatory

1.1 Funding and Background

The Anglo-Australian Observatory (AAO) is jointly funded by the Australian and British governments through DEST and PPARC respectively.

In 1969 the Australian and British governments decided to establish and operate a large optical telescope in Australia for use by Australian and British astronomers. The Anglo-Australian Telescope Agreement Act 1970 gave effect to this decision. The Act established the Anglo-Australian Telescope Board (AATB), a body corporate, which owns and operates the telescope. The Anglo-Australian Telescope (AAT) was opened in 1974. In 1988, the operation of another telescope on Siding Spring Mountain, the UK Schmidt Telescope (UKST), was transferred to the AATB. These two telescopes, together with the Marsfield headquarters facility and instrumentation laboratory, collectively form the Anglo-Australian Observatory. Further information can be found on the AAO website (http://www.aao.gov.au/) and in its Annual Reports (http://www.aao.gov.au/annual/).

1.2 Role of the Facility

The mission of the Anglo-Australian Observatory (AAO) is to provide world-class optical and infrared observing facilities that enable Australian and British astronomers to carry out excellent science. The AAO is a world leader in astronomical research and in the development of innovative telescope instrumentation. It also takes a leading role in the formulation of long-term plans for astronomy in Australia.

The AAO has been a major contributor to Australian and British astronomical research for the past thirty years. Each semester the AAO telescopes typically provide observing time to between 50 and 60 observing programs involving between 150 and 250 astronomers (on average 40% Australian, 40% British and 20% other). Time on the AAT is typically oversubscribed by a factor of between 2 and 2.5. Each year about 140 papers are produced using observations with the AAT or UKST. Of the 318 astronomers or students currently located at Australian institutions, 114 (36%) have used the AAO telescopes in the past 5 years. A review in 2000 by the European Southern Observatory showed that of the eight 4-metre class telescopes in the world, the AAT had the highest publication rate. Many of the papers based on AAT or UKST data are highly cited in the scientific literature. Of the 300 most-cited papers produced by the international astronomical community over the last three years (the top 0.5% of all papers), 17 made use of AAO telescopes.

1.3 High Profile Work Done by the Facility

The 2dF Galaxy Redshift Survey, a map of 221,000 galaxies, measured the amounts of dark matter, baryons and neutrinos in the universe, and is one of the fundamental contributions to the standard model for the age, structure and constituents of the universe. The follow-up 2SLAQ survey is using the 2dF and AAOmega instruments on the AAT to look at galaxies and QSOs at high redshift detected by the Sloan Digital Sky Survey in order to probe the evolution of large-scale structure.

The RAVE project is using the 6dF instrument on the UKST, and aims to measure the orbits for a million stars in the Milky Way over the next 5 years, in order to find out how, and when, our galaxy was formed.

The Anglo-Australian Planet Search (AAPS) has discovered 20 planets around other stars and revealed the existence of worlds unlike any in the Solar System. As the AAPS time baseline increases over the next several years, the range of detectable planet types and the sample of stars searched will both be extended.

Other high-impact research from the past few years that resulted from the AAO telescopes includes (1) the discovery of a new type of galaxy, the first in more than 70 years, (2) the use of stellar seismology to probe the interiors of stars, (3) the discovery of some of the most distant objects in the universe, (4) the identification of massive gamma-ray bursts with exploding stars and (5) the discovery of a satellite galaxy being torn apart by the Milky Way.

1.4 Immediate Future of Facility

The AAT Agreement and the new Supplementary Agreement provide for the continuation of the bi-national partnership until 30 June 2010. Over this time frame the AAO will continue to provide observing facilities to Australian and British astronomers. However the UK will halve its funding contribution in 2006 – 7 and again in 2007 – 8. The British share of time will be reduced pro-rata, and the Australian share will increase from 50% in semester 06A to ~67% in 06B and 07A, and then to ~80% from 07B to 10A. Contributions to the AAO's Joint Program over and above the recurrent contributions may vary these expected shares. Recent and ongoing streamlining of the AAO operations will permit the current level of telescope support to be maintained throughout this period despite the reduction in recurrent funding by the UK. The AAO's instrumentation program will also need to be funded largely from external income in the form of instrument contracts (e.g., WFMOS for Gemini) and competitive grants. (Although UK recurrent funding will be reduced, the AAO is now eligible for PPARC grants. The AAO is not eligible for ARC grants.)

Scientifically, the AAO has much to look forward to. The current instrument complement (2dF, IRIS2, UCLES/UHRF, WFI) is very broadly capable. This capacity will be significantly extended with the advent of the AAOmega spectrograph, which will be the most powerful survey spectrograph in the world from the time it comes on-line in semester 06A until WFMOS is built. The larger fraction of time available to Australian astronomers will enable larger, more ambitious projects to be undertaken with any of the AAT's instruments.

1.5 Future Vision of Facility

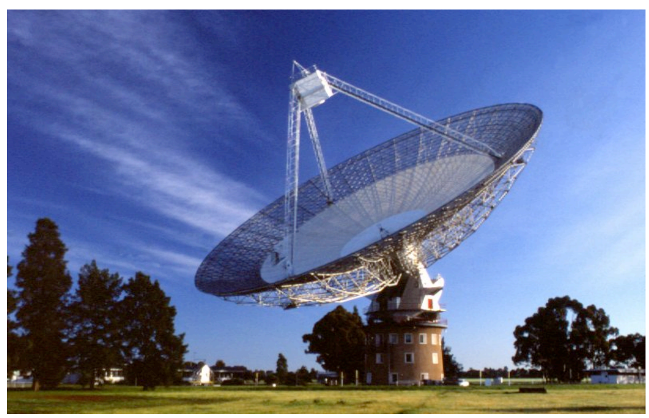
The vision for the future of the AAO is captured in the following recommendations:

1. ***The AAO should be the national organization that supports all of Australia's major optical/infrared astronomy facilities.***
   The AAO (as the Anglo-Australian Observatory up to 2010 and as the "Australian Astronomical Observatory" thereafter) should not only operate the AAT and UKST, but also be the support organization for Gemini and manage Australia's involvement in other major new optical/infrared facilities (e.g. an ELT, an Antarctic telescope, etc.).

2. ***The AAT is an essential facility for Australian astronomers throughout the decade 2006 – 2015, with at least one major new instrument required to maintain its scientific competitiveness.***
   Australia needs not only to maintain the AAT under the Supplementary Agreement for the first five years of the decade (2006 – 2010), but also take sole responsibility for the telescope after the end of the Agreement (2010 – 2015) and ensure that it has suitable instrumentation.
3. ***A major new optical/infrared facility is required around the end of the decade. At the appropriate time, the AAO would transfer its resources from supporting AAT operation to supporting operation of this new facility.***
   Australia should be aiming to obtain access to an ELT, Antarctic 8 m, or equivalent major new optical/infrared facility by around 2015. The AAO, in its role as national optical/infrared observatory, would re-direct the operations cost of the AAT to operating/supporting this new facility. This may mean operating the AAT in full-cost-recovery mode, converting it to other purposes, or closing it down. A plan for a graceful transition is required.
4. ***The AAO instrumentation program is a world leader and should be retained and developed as a national asset.***
   The AAO should remain a source of innovative technology that gives Australian astronomers access to the best instruments on the best telescopes. Australia benefits from the AAO's instrumentation program and should be prepared to invest in it at its current level or better.

2 The Australia Telescope National Facility

2.1 Funding and Background



The Australia Telescope National Facility (ATNF) receives approximately 70% of its funding by direct appropriation from CSIRO and 30% from external sources.

The ATNF became a National Facility in 1990 for operation by CSIRO. The Australia Telescope consists of eight radio-receiving antennas: the six 22 m antennas of the Australia Telescope Compact Array (ATCA), the 22 m Mopra telescope and the 64 m Parkes Telescope. The ATCA has receiver systems covering frequencies from 1.2 to 106 GHz and a maximum baseline length of 6 km. The Parkes Telescope has receivers operating from 440 MHz to 22 GHz.

The ATNF's mission is to operate and develop the Australia Telescope as a national research facility for use by Australian and international researchers, to exploit the telescope's unique southern location and technological advantages to maintain its position as a world-class radio astronomy observatory, and to further the advancement of knowledge. The ATNF is the largest single astronomical institution in Australia; approximately 90% of the Australian radio astronomy is carried out through the ATNF. In the world context, the Australia Telescope is one of the world's most powerful radio astronomy facilities and is the only major radio telescope in the southern hemisphere.

2.2 Role of the Facility

ATNF Usage: The ATNF is operated as a national facility with time granted by the Time Allocation Committee on the basis of scientific merit. In general the time requested for the ATCA and Parkes exceeds the time available by about a factor of two. Typically 40% of scheduled time on the ATCA and Parkes is allocated to proposals with Principal Investigators (PIs) from overseas institutions. The other 60% of scheduled time is allocated to proposals with PIs at the ATNF and other Australian institutions.

Publications: On the basis of the number of refereed articles published with ATNF data each year, ATNF is the second most prolific radio facility in the world. The number of publications per year using AT data has been slowly increasing over the past 10 years, with about 120 refereed papers published in 2004. The ratio of papers published using data from the VLBA, Parkes and the Compact Array is approximately 1:4:7.

Student Training: ATNF supports an active program of student supervision. In 2004 there were 33 PhD students co-supervised by ATNF staff. The ATNF also offers, through CSIRO, on average two top-up scholarships to exceptional students pursuing ATNF-affiliated PhDs.

2.3 High Profile Work Done by the Facility

Science Programs: The ATNF has a long history of major scientific achievements. Some high impact projects recently carried out using the ATNF facilities include:

- The Parkes Multibeam Pulsar Survey
- The HI Parkes All-Sky Survey (HIPASS)
- The ATCA Surveys of the Magellanic Clouds
- The Southern Galactic Plane

Other high-impact research from the past few years includes:

- The first double pulsar
- Carbon monoxide in High-Redshift Galaxies
- A new spiral arm for the Milky Way
- Dense molecular gas heated in starburst galaxies
- Discovery of a super-massive spiral galaxy

Technology and Instrumentation: The ATNF has a very strong instrumentation group, specialising in the design and construction of radiofrequency receivers and high speed digital signal processing. The ATNF pioneered the use of cm-wave multibeam receivers for radioastronomy with the 13-beam 21cm receiver on the Parkes telescope. The development of the recently completed 12/3.5mm systems for the Compact Array has included novel designs and fabrication techniques for microwave polarizers, 3-mm feed horns, and amplifiers both for the first stage and for LO generation and frequency conversion.

New generations of radioastronomy instrumentation are increasingly being developed with the FPGA (Field Programmable Gate Arrays) and MMIC (Microwave Monolithic Integrated Circuit) technologies. ATNF is leading the MMIC technology field with a variety of applications on the ATCA.

2.4 Immediate Future of the Facility

The ATNF will continue to schedule its telescopes in two six-month terms per year, starting in April and October. Major observing programs expected to use ATNF telescopes over the coming years include the ATCA 20GHz survey, the Local Volume HI survey (LVHIS), the Galactic All-Sky Survey (GASS) at 21cm and the pulsar timing array observations at Parkes.

Current development projects and upgrades planned for the immediate future will enhance the technical capabilities of all ATNF instruments. Upgrades presently underway for the ATCA include the increase of the signal processing bandwidth from 128 MHz to 2 GHz, and new receivers for the 7mm band (26-50 GHz). Planned upgrades for Parkes are a new digital filter bank with 1GHz bandwidth, 1024 channels, and synchronous pulsar integration with up to 1024 bins per period, and a 7-beam receiver to operate in the 6.0 – 6.7 GHz band. The Long Baseline Array will receive a major upgrade in the form of gigabit links between the sites to allow for real-time correlation.

2.5 Future Vision of the Facility

Over the next decade the ATNF hopes to position itself to be a major partner in, and possibly host, the next generation international radio telescope, the Square Kilometre Array (SKA). To that end the ATNF is involved in engineering development projects to develop SKA technology. By early next decade, the ATNF – together with Australian and international partners – aims to have built and to be operating a major "pathfinder" instrument for the SKA. As part of this process the ATNF is working to develop infrastructure at the proposed Australian site for the SKA at Mileura, Western Australia by building a telescope operating at 0.7 – 2.4 GHz with 5000 m^2 of collecting area. The ATNF also hopes to lead development of an SKA pathfinder instrument to carry out the science that will lead us to the SKA. Simultaneously, the ATNF will continue to enhance its position as a world-class radio astronomy observatory through on-going developments for the ATCA and Parkes.

3 Australian National University: Siding Spring Observatory

3.1 Funding and Background

The Siding Spring Observatory (SSO) is funded by the Australian National University. The 40-inch, 24-inch and 16-inch reflectors at SSO were acquired during the 1960s. The 2.3 m telescope, constructed in-house by ANU, began operation at SSO in 1984. The astronomy research institute at ANU, which operates SSO, has changed name several times since 1956. It is now known as the Research School of Astronomy and Astrophysics (RSAA), and as such is part of the Institute for Advanced Studies at the ANU.

3.2 Role of the Facility

The RSAA itself is funded as a university research school, through the ANU, and through competitive national funding and external contracts. It receives no funding specifically for the operation or maintenance of its telescopes. As such, ANU telescopes constitute a university facility, rather than a national facility, although they are available for use in open competition to all Australian and overseas astronomers. Due to the nature and extent of primary funding source for ANU telescopes, the degree of observer and instrumentation support cannot necessarily match that of the National Facilities. Nevertheless, the two major RSAA research telescopes enjoy a wide range of users. Statistics on telescope usage of the 40-inch and 2.3 m at SSO by RSAA and non-RSAA astronomers for the years 2001 – 2003 show that fewer than 25% of applications are the result of RSAA-only programs.
RSAA is also active in instrument building, with two current contracts for major multi-million dollar Gemini instruments (the NIFS spectrometer and the GSAOI adaptive optics imager), other smaller external contracts, and some large internal instrument projects (the SkyMapper telescope and the WiFeS spectrometer for the 2.3 m telescope).

3.3 High Profile Work Done by the Facility

Recent high profile work includes the discovery of the accelerating universe, the MACHO, RAVE, 2dFGRS and HIPASS projects, discovery of the most metal-poor stars, the chemical abundance of the sun, and models for starburst galaxies.

3.4 Immediate Future of the Facility

The RSAA facilities on Siding Spring will continue to be available to Australian and international astronomers. Remote operation of the SSO telescopes and instruments is a major goal for the near future, and this is being facilitated by a DEST Systemic Infrastructure Initiative (SII) grant. This initiative will also partially fund a high-speed link from Siding Spring to major Australian institutions to allow faster data transfer, and thus, ultimately some remote observer capabilities. Fabrication will soon begin on an advanced IFU spectrometer (WiFeS) for the ANU 2.3 m telescope, also funded by the SII grant. This will greatly increase the spectrometric capability of this telescope. The expected high throughput and relatively high resolution of WiFeS will enable detailed studies of high redshift galaxies with a telescope that is relatively small by today's standards.

3.5 Future Vision of the Facility

As part of the Stage I rebuild of the lost capability suffered by RSAA as a result of the 2003 bushfires, ANU has decided to invest in two RSAA facilities that will ultimately benefit all Australian astronomers. Firstly, the Skymapper, a 1.3 m wide-field telescope currently under construction by EOS with a CCD detector array system being built in-house by RSAA, will be used initially for a "Southern Sloan" sky survey, with part time reserved for open competition. Secondly, a new Advanced Instrumentation and Technology Centre (AITC) is under construction on Mount Stromlo itself that is purpose-built to enable the conception, design, manufacture and assembly of instruments for the next generation of optical/infrared telescopes. Adaptive optics will be a major focus in technology development, and student PhD programs in astronomical instrumentation are already being offered.

4 The Australian Virtual Observatory

4.1 Funding and Background

Work on Aus-VO in 2004 and 2005 was partly funded by Australian Research Council Linkage Infrastructure (Equipment and Facilities) grants. The project partners are the Universities of Melbourne, Sydney, New South Wales and Queensland; Monash University, Swinburne University of Technology, the Australian National University, the Victorian Partnership for Advanced Computing, the CSIRO Australia Telescope National Facility and the Anglo-Australian Observatory. These organizations provide matching funds totalling about 33% of the total cost of the projects supported. Additional funding for future years has been requested from the ARC.

The Australian Virtual Observatory (Aus-VO, see http://www.aus-vo.org/) will be a facility that provides a distributed, uniform interface to the data archives of Australia's major astronomical observatories, and to archives of astrophysical simulations. Aus-VO will be a key component of the International Virtual Observatory, a worldwide facility which will link the archives of the world's major astronomical observatories into one distributed database. Aus-VO has been a founding member of the International Virtual Observatory Alliance (IVOA, see http://www.ivoa.net/pub/info/) since June 2002. Annual Aus-VO workshops with international speakers have been held in 2002 – 2004. Overseas, the total investment of funds in IVOA projects is more than $20 million (US) over the next three to five years.

4.2 Role of the Facility

The IVOA has a mainly coordinating role, defining standards etc, notably the "VOTable" format for data transfer. The tools and services will be provided by individual national VOs. The Aus-

VO will focus on the VO-compatible archiving of major data sets from Australian observatories as well as developing specific software tools to analyse these data sets. Examples of the former include the ATNF ATCA on-line archive (in collaboration with CSIRO ICT). Software tools under development include the ATCA data processing pipeline, a remote visualization system, automated catalogue linkage techniques and data-mining tools.

4.3 High Profile Work Done by the Facility

It is too soon to expect high-impact papers from Aus-VO work yet, but there are already some interesting results from the international work. These include the discovery of new optically faint obscured quasars and the discovery of new samples of brown dwarf stars.

4.4 Immediate Future of the Facility

There are active Aus-VO programs underway at several Australian universities and observatories plus CSIRO as listed above. This has been jointly funded by the institutions and the ARC, so will continue at a reduced rate if not directly funded by the ARC. The immediate outcomes of this work will focus on the delivery of high-quality legacy data products from major Australian observational surveys, as well as the development of several specific data mining and visualisation tools. In 2005 the critical process of unifying the various components of the Aus-VO will commence, using the GrangeNet network backbone.

4.5 Future Vision of the Facility

It will take a further 3 years (2005 – 2007) to establish a fully functional Aus-VO. This involves the continued development of VO-compatible data products, new visualisation and data-mining software, and the network infrastructure and hardware needed to support the project.

5 PILOT: Pathfinder for an International Large Optical Telescope

5.1 Funding and Background

PILOT (Pathfinder for an International Large Optical Telescope) is a 2 metre optical/IR telescope capable of diffraction-limited performance at 550 nm. PILOT is to be located at the French /Italian Concordia station at Dome C, Antarctica. A comprehensive science case for PILOT is available at http://www.publish.csiro.au/nid/138/paper/AS04077.htm

This is a proposed new facility, not yet funded. Assuming that Australia initially provides the telescope and dome, and European collaborators initially provide logistics, adaptive secondary and first-light instruments, the cost to Australia is A$6m spread over three years ($2m/year) beginning immediately, with an annual operation cost of around $1m/year after that. If Australia paid for everything then the cost would be twice this; however this is an unlikely scenario because access to Concordia station would necessarily entail European involvement anyway.

5.2 Future Vision of the Facility

This facility would give Australia a new, unique and highly diverse scientific capability within next 5 years, securing Australia's position as world leader in Antarctic astronomy. Other advantages are that it helps secure Australia's political presence on the Antarctic plateau and leverages our involvement in important overseas technologies such as Arcetri's adaptive secondary mirror. An Australian company (EOS) is keen to participate and could be the prime contractor.

6 Theoretical Astrophysics

We recommend that a specific plan be developed to resource the integration of theoretical and computational infrastructure into National Facilities. Such integration cannot be sustained solely on the back of ARC grant funding to theoretical and computational astrophysicists in universities. At the present time, approximately $1M per annum in ARC DP funding (including fellowships) comes to astronomy, and there is the possibility of securing a similar additional amount through a Centre of Excellence. Even in an extreme scenario where these resources are devoted entirely to scientific (including theoretical and computational) support of National Facilities, they are insufficient (as a percentage of the capital and operating costs of a $100M-class facility) to ensure that the scientific impact of the facilities is maximized (at least, that part of the impact which is identifiably Australian).

7 Mileura Widefield Array: Low Frequency Demonstrator

7.1 Funding and Background

The Mileura Widefield Array: Low Frequency Demonstrator (MWA-LFD) is a new telescope planned for construction during the period 2006 – 2008 on the radio-quiet site in WA that is proposed for the SKA. The telescope will operate in the frequency range 80 – 300MHz, which is a largely unexplored region of the radio spectrum. The telescope is a partnership between MIT and Harvard in the US and a consortium of Australian universities, ATNF and the Government of WA. The project is being led by MIT, who have invested heavily in the technical design and development of the telescope up to this time. The website is http://web.haystack.mit.edu/arrays/MWA/site/index.html.

The Australian partners are covering the cost of their early engagement from their own internal funds. Significant funding (~$70k) has been contributed by the University of Melbourne for the early deployment. ANU, ATNF and Curtin University are funding their own participation, which involves travel to the site and accommodation, and staff resources. The Australian partners will submit an ARC LIEF grant in 2005 and 2006 for a total of $1M. This will be matched by a substantial investment by ATNF and WA Govt of common funding for the LFD and xNTD. The US partners have requested US$4.5M for the project.

7.2 Future Vision of the Facility

The rate of progress for the construction of the telescope will depend substantially on the flow of funds. If the funding from the ARC and NSF is secured, then the timescale for completion of the telescope will be the end of 2007. However if this funding is not secured, it will take longer to build the facility.

The LFD will be a ‘campaign-based’ science facility, not a national facility. This means that individual groups will need to obtain funding to use the telescope for particular experiments. The primary science projects at this stage are detection and mapping of the epoch of reionisation, heliospheric science and detection of radio transients.